INCREASING THE PRODUCTIVITY OF SEMI-DESERT SHRUB-GRASSLAND COMMUNITIES

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INCREASING THE PRODUCTIVITY OF SEMI-DESERT SHRUB-GRASSLAND COMMUNITIES[1]

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Summary

Determining the effects of velvet mesquite (*Prosopis velutina*) overstory removal, post-treatment control of sprouting, and mulching treatments on herbage production (standing biomass) and selected soil chemical properties on the Santa Rita Experimental Range were the objectives of this study. Mesquite overstory treatments consisted of complete overstory removal with and without the control of the resulting re-growth of stump sprouts. The mulching treatments were applications of mesquite wood chips, commercial compost, and lopped-and-scattered mesquite branchwood. Herbage production was estimated in the spring and early fall to determine total annual production and the production of early growers and late growers. Mesquite overstory removal resulted in increases in herbage production. However, mesquite removal had no effect on the soil chemical properties considered. The mulching treatments did not have an affect on herbage production, although some of the soil chemical properties were affected by some of the mulching treatments.

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INTRODUCTION

Increases in woody plants such as velvet mesquite (*Prosopis velutina*) have been a long-time concern of rangeland managers and livestock producers in the southwestern United States because this encroachment has often reduced forage resources and, therefore livestock production (Herbel et al. 1983, Heitschmidt and Dowhower 1991, Martin and Morton 1993, Laxson et al. 1997, and others). The encroachment of mesquite onto otherwise productive semi-desert grass-shrub rangelands has been attributed to earlier overgrazing by livestock, reduced frequency of fire, and changes in climatic patterns (Fisher et al. 1973, Martin 1975, Herbel 1979, McPherson 1997, and other). One reason for establishment of the Santa Rita Experimental Range in southern Arizona was to study methods of restoring the often depleted rangeland conditions brought about by earlier heavy livestock grazing. Among these strategies was improving rangeland conditions by controlling the invasion of mesquite and other woody plants.

The intent of this study was to determine the changes in herbage production (standing biomass) and selected soil chemical properties that might affect herbage production in response to mesquite overstory removal with and without the control of the resulting re-growth of stump sprouts, the addition of mulch, or combinations thereof. Information of this kind could be incorporated into management practices to enhance the productivity of semi-desert grass-shrub rangelands in the future. Preliminary results of the study have been presented by Pease et al. (2000, 2003). A more comprehensive presentation of the study, including background literature, supporting tables and illustrations, and summaries of the statistical analyses of the source data collected in the study is found in Pease (2000).

DESCRIPTION OF STUDY

The study area was located within the Desert Grassland Enclosure on the Santa Rita Experimental Range, an area that had not been grazed by livestock for 70 or more years before the study was initiated. Descriptions of the climatic patterns, soil and other physiographic features, and vegetation resources of the Experimental Range have been presented elsewhere (Martin 1966, 1975, Martin and Reynolds 1973, Severson and Medina 1981, Medina 1996, and others) and, therefore, need not be included here. Within the study area, mesquite trees and shrubs dominates the woody overstory and Lehmann lovegrass (*Eragrostis lehmanniana*), an introduced species that was initially planted on the Experimental Range in 1937 (Cable 1971, Ruyle and Cox 1985, Cox and Roundy 1986, and others), is the dominate species in the herbaceous understory. Native perennial herbaceous species on the area include *Eriogonum wrightii*, *Solanum elaegnifolium*, *Haplopappus tenuisectus*, and *Gnaphalium purpureum*, while common annual species are *Chenopodium album*, *Eschscholtzia mexicana*, and *Descurainia pinnata*. There are two growing seasons for the herbaceous plants on the Santa Rita Experimental Range. One season occurs in early spring when temperatures and antecedent soil moisture are favorable, while the other season is late summer or early autumn in response to summer rains.

Study Design and Treatments

The completely randomized study design consisted of 60, 5-by-5 m plots containing a mesquite tree or shrub in the center of the plots. A minimum buffer of 1 m was located between the plots. The plots were blocked on the basis of information obtained from a pre-treatment mesquite overstory inventory that indicated the structure (tree or shrub) and size of the mesquite on the plot. Treatments were then randomly assigned to the plots in a manner that the insured the range of mesquite structures and sizes would be included within each treatment combination. The

treatments, applied in early July 1995, consisted of 3 overstory removal treatments and 4 mulching treatments within each of the overstory treatments. Each combination of overstory removal treatment and mulching treatment was replicated 5 times. The three overstory treatments were complete removal of the mesquite overstory with a power saw with and without the control of the resulting re-growth of stump sprouts hand cutting in July 1997 and an untreated control. The mulching treatments included applications of a chip mulch, a commercial compost, lopped-and-scattered mesquite branchwood, and a control. The chip mulch, obtained by chipping the cut mesquite branchwood to 1 cm or less in diameter, was uniformly distributed on the plots to a depth of 15 to 25 mm. The commercial compost was fir-based with 0.5% nitrogen, 0.1% iron, and 0.2% sulfur. Approximately 0.25 m^3 of the compost was applied to the plots. The lopped-and scattered mesquite branchwood was spread to completely cover the plot.

Data Collection

Herbage production was estimated by species on 0.89 m^2 plots in May and October in 1995 through 1999 by the weight-estimate method of sampling originally described by Pechanec and Pickford (1937). (Observations made in April 2000 indicated that there had been little change in herbage production among the treatments since 1999 and, therefore, estimates of herbage production were discontinued.) The sub-sample herbage samples collected to develop the necessary factors to convert the estimates of actual herbage production were dried, separated by plant species, weighted, and extrapolated to kilograms per hectare.

The selected soil chemical properties were sampled annually in May 1995 through 1998. A composite of 12 sub-samples was obtained from the top 5 cm of the soil on each plot. The soil samples were collected along a diagonal transect situated across the plots with 0.3 m between the sub-samples. The samples were analyzed for total nitrogen, nitrate, total organic carbon, total

phosphorus, plant available phosphorus (Olsen phosphorus), and pH at the Soil, Water, Plant Analysis Laboratory of the University of Arizona, Tucson, Arizona. These soil chemical properties were selected to provide a basis for a comparative analysis of the results obtained in this study and a counterpart investigation on controlling shrub cover to increase grass productivity in northern Israel (Perevolotsky et al. 1998). This counterpart investigation was also supported by the USDA Forest Service. A sub-sample of soil was collected in May 1995 and 1997 for analysis of microbial activity by the dehydrogenate method.

Annual precipitation (mostly rainfall) was measured by a standard weighing gage located near to the Desert Grassland Enclosure. The average annual precipitation in the study period of 1995 to 1999 was 369 mm, an amount of that was nearly one-third below the long-term average precipitation on the Santa Rita Experimental Range. It was assumed that precipitation affecting early spring (early) growers fell from November through May, while the precipitation that fell from June through October impacted the late summer-early autumn (late) growers.

Data Analysis

Analyses of variance were conducted to determine whether significant differences occurred in herbage production and the selected soil chemical properties among the overstory removal and/or mulching treatments. Herbage production of early growers and late growers was analyzed separately. Tukey-Kramer HSD was used to determined which treatment(s) had significantly different effects on herbage production (Williams 1993). All statistical analyses were evaluated at a 0.10 level of significance.

RESULTS AND DISCUSSION

Total Herbage Production

Total herbage production consisting of about 90% perennials and 10% annuals averaged 1,896 ± 115 kg/ha/yr (mean ± standard error) from 1995 to 1999 on the plots receiving the two mesquite overstory removal treatments and 1,554 ± 94 kg/ha/yr on the control plots. Control of the resulting re-growth of stump sprouts did not significantly affected total herbage production. Reduced competition between the mesquite and herbaceous plants for soil moisture likely contributed to the increased total herbage production on the treated plots. However, the observed increase was less than that reported in earlier studies of herbage responses to the removal of mesquite overstories (Herbel et al. 1983, Heitschmidt and Dowhower 1991, Martin and Morton 1993, Laxson et al. 1997, and others). Only the tops of the mesquite trees and shrubs were removed in this study, while the cited studies involved total killing of the mesquite. It was possible, therefore, that the mesquite were still competing with herbaceous plants for soil moisture.

The effect of the mesquite overstory removal on the annual production of Lehmann lovegrass was analyzed separately because of the dominance of this species on the study area and, more generally, the Santa Rita Experimental Range. However, these overstory removals had no effect on the annual production of Lehmann lovegrass. The production of Lehmann lovegrass on all plots in the study regardless of the treatment imposed averaged 1,574 ± 87 kg/ha/yr for the study period. It appears that Lehmann lovegrass was not competing with mesquite trees and shrubs for soil moisture. This conclusion is supported by earlier research that suggests that (a) Lehmann lovegrass is capable of persisting and spreading in areas where precipitation within a 40-day summer period is 90 mm or more (Anable et al. 1992) and (b) the species is well adapted to

surviving on sites where the total summer precipitation is 200 mm or more (Robinett 1992). Because the summer precipitation in most of the years in this study was greater than these threshold amounts, it might be that the production of Lehmann lovegrass was not constrained by a lack of summer soil moisture.

The annual production of native herbaceous species averaged 251 ± 47 kg/ha/yr on the plots receiving the mesquite overstory removal treatment with no post-treatment control of re-sprouting and 140 ± 20 kg/ha/yr on the control plots. Post-treatment control of the mesquite re-sprouting did not affected the production of native herbaceous species. The almost 80 percent increase in the average production of native species on the plots with the overstory removal treatment and no control of re-sprouting suggests that the native species competed directly with mesquite trees or shrubs for soil moisture and, therefore, responded positively to the removal of mesquite overstories.

The mulching treatments had no impact on total herbage production, the production of Lehmann lovegrass, or the production of native herbaceous species. These results were attributed largely to the below average precipitation in the study period and, to some extent, the possibility that inadequate levels of mulch were applied to the plots to affect soil moisture availability. Biedenbender and Roundy (1996) suggested that mulching treatments might not sufficiently affect soil moisture availability in periods of low and infrequent rainfall and, as a consequence, the establishment and growth of herbage plants.

Seasonal Herbage Production

Mesquite overstory removal had no effect on the production of early herbage growers. This finding was largely attributed to the (48%) below average in precipitation in the time period

affecting this growing season. However, the average production of late herbage growers on the plots with mesquite removal and no post-treatment control of re-sprouting was greater (1,278 ± 89 kg/ha/yr) than on either the plots with overstory treatments and post-treatment control of re-sprouting or the control plots. The average production of late growers was statistically the same (1,042 ± 69 kg/ha/yr) on these latter plots. Shade provided by the re-sprouting mesquite could have been a causal factor for the observed increase in late growers (Shrive 1931, Tiedemann 1970). Shrive (1931) concluded that the environment under the mesquite canopies was favorable to the production of late growing annual and perennial herbaceous plants. The soil temperature is significantly lower and soil moisture higher under mesquite canopies in the time when the late growing herbage is developing at its maximum.

Neither spring nor fall production of Lehmann lovegrass nor the production of early growing native herbaceous species was affected by mesquite overstory removal. However, the average production of late growing native species was greater (167 ± 40 kg/ha/yr) on the plots receiving the two mesquite overstory removal treatments than on the plots with overstory removal treatment and post-treatment control of re-sprouting or the control plots (62 ± 16 kg/ha/yr). Post-treatment control of re-sprouting did not affected the level of production. The shade provided by the re-sprouting mesquite was a likely causal factor.

The mulching treatments had no affect on the production of either the early or late growers. Interactions effects between the mesquite overstory removal and mulching treatments on total herbage production, the production of Lehmann lovegrass, and the production of early or late growers were all insignificant.

Soil Chemical Properties

The mesquite overstory removal treatments had no impact on the soil chemical properties evaluated. This result was not necessarily surprising given the comparatively slow rate of nutrient cycling in semi-desert grass-shrub ecosystems such as that represented on the Santa Rita Experimental Range. While earlier studies examined the effects of standing mesquite overstories on soil chemical properties (Tiedemann and Klemmedson 1973, Barth and Klemmedson 1978, Virginia and Jarrell 1983, and others), only limited research has been conducted on the effects of removing mesquite trees and shrubs on soil chemical properties. A decline in nutrient availability 13 years following the removal of mesquite on the Experimental Range was observed by Klemmedson and Tiedemann (1986). However, the duration of this current study might not have been of sufficient length to adequately reflect the impacts of mesquite overstory removal on the soil chemical properties evaluated.

The mulching treatments had no significant effects on nitrate, total organic carbon, or total phosphorus levels of the soil. But, these treatments did affect the levels of total nitrogen, plant available phosphorus, and pH of the soil. Total nitrogen was higher on the plots with a mulch of lopped-and-scattered mesquite branchwood than the control plots. The plots receiving the compost and chipped mulches had a higher pH than the control plots. There was a negative correlation between pH and plant available phosphorus on the plots with the compost and chipped mulches. Reasons for the specific changes observed in these soil chemical properties are unclear, the observed changes were comparatively small in their magnitude, and their impacts on herbaceous plant growth unknown. The microbiological analysis of the soil samples proved inconsistent and largely inconsequential.

Interaction effects between the mesquite overstory removal and mulching treatments on the

selected soil chemical properties were insignificant or inconsistent.

MANAGEMENT IMPLICATIONS

Complete removal of a mesquite overstory without a follow-up control of the resulting stump sprouts has the greatest affect (of the treatments evaluated in this study) on increasing total herbage production, especially in years of average or above average annual precipitation. This treatment is likely to be most effective on semi-desert grass-shrub rangelands that have an understory of predominantly native herbaceous species. The production of Lehmann lovegrass was not affected by either of the overstory removal treatments tested in this study. While it has been concluded from earlier studies in southern Arizona that mesquite overstory removal generally results in an increase in the annual production of both native herbaceous species and Lehmann lovegrass (Kincaid et al. 1959, Cable and Tschirley 1961, Cable 1976, Martin and Morton 1993, and others), the amount of annual precipitation might partly explain the apparent discrepancy between the results of these cited studies and the study reported in this paper. Sites of the earlier studies received more annual precipitation than the Desert Grassland Enclosure in the years of this current study. The results from this current study suggest that in areas that have predominantly Lehmann lovegrass understories and receive less than 380 mm of annual precipitation, an overstory treatment of top removal of mesquite might not increase annual herbage production enough to justify this treatment if the objective of management is solely to increase herbage (forage) production.

The mulching treatments tested in this study were ineffective in increasing the level of annual herbage production. It is possible that the amounts of mulch that were applied to the plots were insufficient to alter evaporation rates to levels that significantly affect the soil moisture available to the herbaceous plants. Determining the most effective layering of mulching to apply is a difficult

task (Lemon 1956, Pease 2000). Insufficient amounts of mulching will not change evaporation rates enough to increase soil moisture, while excessive mulching can cause increases to soil temperature which in turn can increase evaporation.

CONCLUSIONS

This study was conducted in a 5-year period of prolonged drought. The departures of 30% or more in average annual and summer precipitation in the study period might have masked the treatment effects on annual herbage production and the selected soil chemical properties. Further investigation of the effects of mesquite overstory removal, controlling the resulting re-growth of stump sprouts, and mulching treatments on herbage production and the soil chemical properties that might affect herbage production is necessary to more completely evaluate the affects observed in this study. Nevertheless, information such as that presented in this paper can be useful to managers in attempting to enhance the productivity and stewardship of semi-desert grass-shrub rangelands in the southwestern United States.

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